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Optimal Location of SMES for Improving Power system Voltage Stability Using PSO algorithm

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ABSTRACT: *Superconducting Magnetic Energy Storage (SMES) system is an equipment that can help to improve the voltage stability of power system. Location of SMES in multi-node power network plays a significant role for the stability improvement level. In this paper, Particle Swarm Optimization(PSO) of the SMES location based on the quantitative voltage stability(L-index). In PSO, voltage stability index is used as the fitness function. The proposed algorithm is tested on IEEE 14-bus system. and best results are obtained.*

Keywords: Particle Swarm Optimization (PSO), optimal location, Superconducting Magnetic Energy storage, voltage stability.

1.INTRODUCTION

Superconducting Magnetic Energy storage (SMES) system stores energy in the superconducting coil and regenerates it to the utility through power conversion circuits. It has two major advantages, of rapid response and high power efficiency. The most important advantage of SMES is that the time delay during charge and discharge is quite short. Power is available almost instantaneously and very high power output can be provided for a brief period of time. Other energy storage methods, such as pumped hydro or compressed air have a substantial time delay associated with the energy conversion of stored mechanical energy back into electricity. Another advantage is that the loss of power is less than other storage methods. Additionally the main parts in a SMES are motionless, which results in high reliability. SMES systems can offer flexible, reliable and fast acting active and reactive power compensation.

The quantitative voltage stability index is typically used as a criterion for such an optimization problem. voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance. In general voltage stability problems occur more frequently in a heavily loaded system. The change in voltage is directly proportional to change in load and hence voltage stability is sometimes termed as load stability. The advantage of this method is the simple numerical calculation and strong adaptation in steady state and transient process, the quantitative voltage stability index varies in the range of 0 and 1 is typically used as a criterion for optimization problem. various methods expressed from a multi-objective optimization technique, were proposed and used for optimal allocation of FACTS devices in power systems. including optimal solutions, genetic algorithm and particle swarm optimization technique.

This paper introduces the application of PSO for optimal location of SMES to improve the voltage stability in a power system.

2. VOLTAGE STABILITY INDEX

In power system, the stability level of all buses and the weakest bus among them are identified with the help of the stability indices. Voltage stability Index (L-Index) is one among them.

The minimum singular value of the power flow Jacobian matrix has been used as a static voltage stability index. VSI indicates the distance between the studied operating point and the steady-state voltage stability limit[3]. Operators can use the index to know how close the system to voltage collapse, or how much power that the system can supply to loads. This index can be used on-line or off-line to help operators in real time operation of power system or in designing and planning operations.

Voltage stability Index is used to calculate the stability indices for all the load buses connected in an IEEE 14 bus network. For a given system operating condition, by using the load flow results obtained from Newton-Raphson Technique, the Voltage Stability index(L-index) for load buses is to be computed follow as

$$L_j = \left| 1 - \sum_{i=1}^{g} f_{ji} \frac{V_i}{V_j} \right| \text{---------(1)}$$

where g is the number of generators connected in the system. j=g+1,…….n. where n is the total number of buses. The values of F_{ji} can be obtained from Y-bus matrix as follows. Where Y_{LL},Y_{LG} are corresponding partitioned Portions of the Y-bus matrix. The

L-indices for a given load condition are computed for all load buses and the maximum of the L-index gives the proximity of the load bus to voltage collapse.

$$F_{ji} = [Y_{LL}]^{-1} [Y_{LG}] \text{ ----------(2)}$$

3, MODEL FOR SMES

Superconducting Magnetic Energy Storage(SMES) system is an energy storage system that stores energy in the form of dc magnetic field, by passing current through the superconductor[1]. The conductor for carrying the current operates at cryogenic temperatures, where it becomes superconductor and thus has virtually no resistive losses as it produces the magnetic field. Consequently, the energy can be stored in a persistent mode, until required.

In general, an SMES system consists of four parts, which are superconducting coil with the magnet (SCM), the power conditioning system (PCS), the cryogenic system (CS), and the control unit (CU)[4], as shown in Fig1.

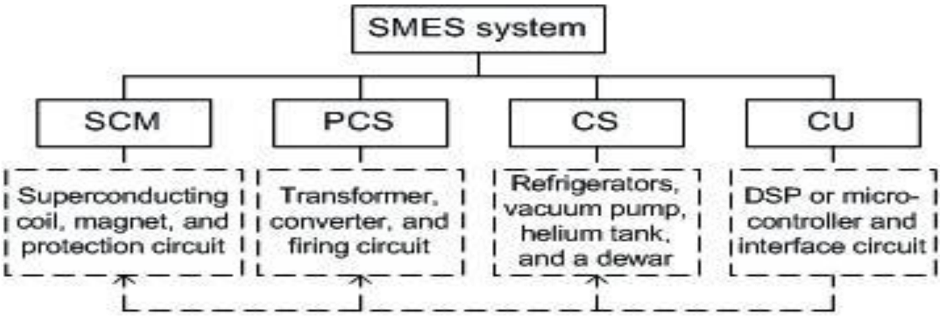

Fig 1.Block diagram of an SMES system

SMES consists of isolated transformers, voltage source converters (VSC), DC converters (DC/DC), and a superconducting magnet coil, as shown in Fig.2

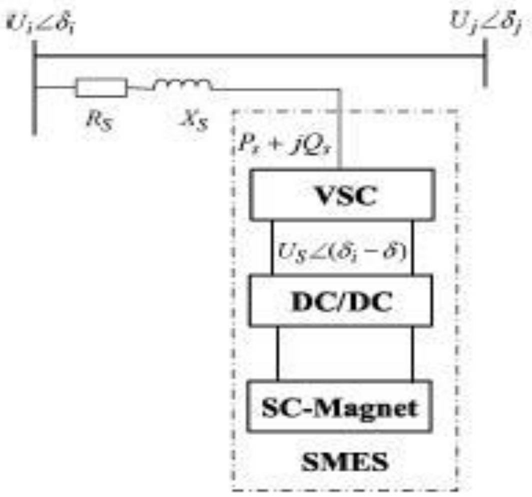

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Fig.2: schematic of SMES system VSC and DC/DC converter

4, PSO ALGORITHM

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Edward and Kennedy in 1995, inspired by social behaviour of bird flocking or fish schooling[10]. The implementation of PSO is as follows

Step1. Set SMES parameters and prepare to solve the stability problem in transmission line.
Step2. Initialize an array of particles with random positions and their associated velocities to satisfy the inequality constraints.
Step3. Check for the satisfaction of the equality constraints and modify the solution if required.
Step4. Evaluate the fitness function of each particle.
Step5.Compare the current value of the fitness function with the particles previous best value (Pbest). If the current fitness value is less, then assign the current fitness value to Pbest and assign the current coordinates(positions) to Pbestx
Step6. Determine the current global minimum fitness value among the current positions.
Step7. Compare the current global minimum with the previous global minimum(gbest).If the current global minimum is better than gbest, then assign the current global minimum to gbest and assign the current coordinates(positions) to gbestx.
Step8. Change the velocities
Step9. Move each particle to the new position and return to step3
Step10. Repeat step3-9 until a stop criterion is satisfied or the maximum number of iterations is reached.

5, RESULTS

The proposed algorithm is tested on the IEEE 14-bus test system[10]. Which consists of two generators, 3 synchronous compensators set at buses 3, 6 and 8, 9 load buses and 20 transmission lines. Then load flow is such on IEEE-14 bus test system. By substituting the corresponding load flow results in the equations (1) and (2) to obtain the VSI values are obtained as shown at table1.

Load Bus Numbers	Voltage stability Index value
4	0.723
5	0.727
7	0.705
9	1.000
10	1.000
11	0.502
12	0.469
13	0.444
14	1.000

Table1. Voltage stability index values

The L index gives a scalar number to each load bus. If the index value (L- index) is moving towards zero, then the system is considered as stable and also improves system security. When this index value moves away from zero, the stability of the system relatively decreases and the system is considered as unstable.

In this test case, VSI at load buses 9, 10 and 14 is 1. So voltage at these buses is about to collapse for any small disturbance. To avoid this, SMES are placed at these locations are optimal locations are obtained by PSO algorithm using voltage stability index.

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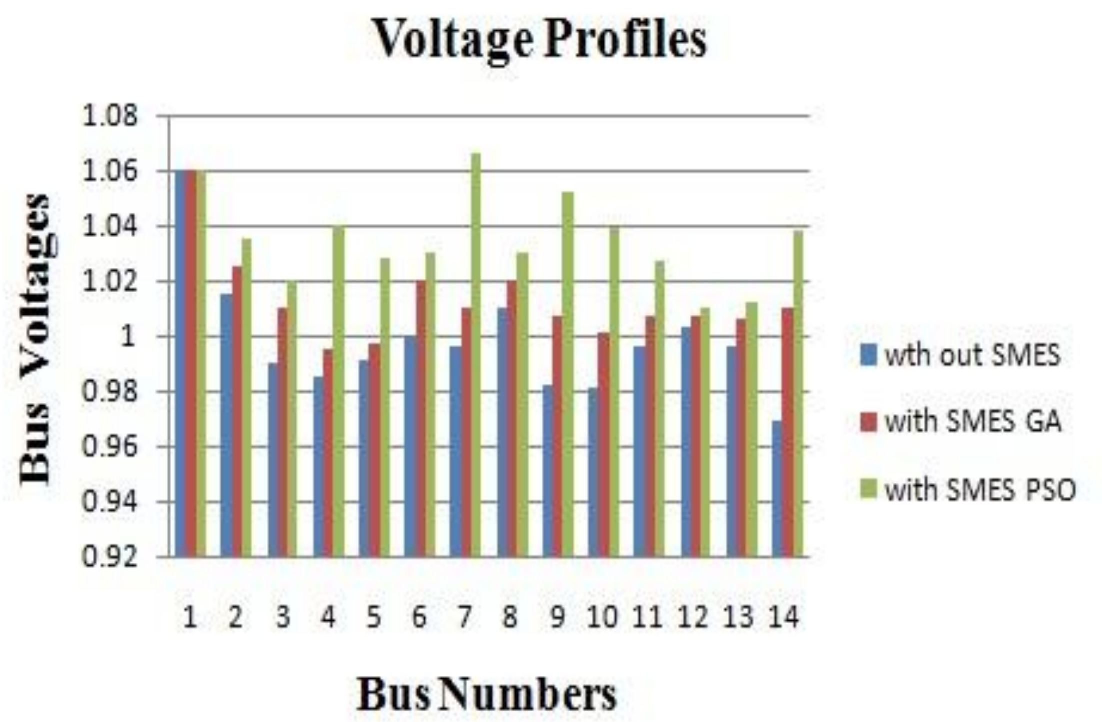

Fig 3.Voltage Profiles with and with SMES GA and PSO

6,CONCLUSION

This paper has demonstrated the application of PSO on location of SMES systems in transmission line, no enhance the voltage stability. Simulation results of IEEE 14-bus test system shown the significant voltage stability enhancement and validate the efficiency of the optimal location of SMES.

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